Mineral Concentrations in True Mountain Mahogany and Utah Juniper, and in Associated Soils

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Abstract

Concentrations of minerals in soils and plants were measured in two communities. Zinc, copper, magnesium, phosphorus, and nitrogen showed significantly ($p < 0.01$) greater concentration in true mountain mahogany than in Utah juniper. Soils beneath plant canopies had significantly higher ($p < 0.01$) nitrogen than soils in open areas between plants. Concentrations of zinc, manganese, and phosphorus were significantly ($p < 0.01$) higher in the soils of the juniper community, while calcium and magnesium concentrations were significantly ($p < 0.01$) higher in the soils of the mountain mahogany community. True mountain mahogany showed copper concentration (x=28.9 ppm) high enough to approach toxic levels for some herbivores. Except for copper, mineral concentrations indicated good forage value for these two species.

Mineral concentrations of range plants in relation to the soils in which they grow may be studied by plants, chemically, and/or by noting malnutrition disorders of animals grazing on them. Generally, plants are materially affected by the nature of the soils in which they grow. Hall (1905) stated that as early as 1869 Hellriegel found that plant nitrogen and mineral composition varied with that of the soil. Crops grown on different soil types vary not only with respect to yield, but also with respect to quality, palatability, nutritive value, and mineral composition (Midgley and Weiser 1936; Russell 1973).

There is a close correlation between the mineral composition of the ash of pasture plants and available soil constituents. Ash of plants grown on infertile acid soils often contains relatively large amounts of silica and other elements such as aluminum, manganese, and iron, whereas the ash of plants grown on fertile soils usually contains relatively large amounts of such elements of phosphorus, potassium, and calcium (Beeson 1941).

It is thought the presence of some elements tends to decrease the palatability of herbage and make it less desirable. For example, plants may be made toxic or less palatable through deposition on their surfaces of certain minerals such as copper (Hill 1951). Subterranean clover *(Trifolium subterraneum)* has been shown to accumulate copper to potentially lethal levels from natural, copper-rich soils (Grahame et al. 1949). Similarly, other minerals such as lead, cadmium, fluorine, and manganese may reach toxic levels in forage (Kingsbury (1964). Although toxic or nonpalatable levels of mineral concentration in forage have not been precisely determined, there is some evidence that both high and low levels may be detrimental. Baker (1974) reports toxicity in sheep due to copper concentrations greater than 20 to 30 ppm in feeds and forages, but concentrations of less than 5 ppm were considered deficient for cattle. High concentrations of copper, however, have been reported to cause impaired performance and poor physical condition in cattle (Underwood 1971).

Animal nutritionists are concerned with the mineral content of plant tissue, since primary consumers derive the major portion of their mineral needs from plants (Harner and Harper 1973). There is close correlation between animal health and mineral concentrations of range plants. Similarly, there is close correlation between mineral concentrations of range plants and their soils. The purpose of this study was to examine the chemical compositions of two species of native range plants in relation to the soils in which they grow and consider the implications for forage value.

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Study Area

This study was conducted in the Uintah Basin, Utah, along the southern foothills of the Uinta Mountains, north and east of the town of Duchesne. From this point the basin floor slopes gently southeast. The elevation in the area ranges between 1,500 and 2,000 m. Annual precipitation averages 26 cm (Greenwood and Brotherson 1978).

Vegetation in the area is predominately pinyon-juniper woodland with interspersed islands of true mountain mahogany *(Cercocarpus montanus).* Although the mountain mahogany community is scatterd among Utah juniper *(Juniperus osteosperma)* communities, there are major differences in the predominant lifeforms associated with these two range plants. The mountain mahogany community is characteristically a grass-shrub association, while the juniper community is typically a tree-annual forb type (Greenwood and Brotherson 1978).

The area shows seasonal moisture deficiency, especially in June. The soils are mainly loamy sands with average depths of 13 cm in mountain mahogany stands and 28 cm in juniper stands. The presence of sandstone outcrops, commonly called slickrock, is common on the mountain mahogany sites (Greenwood and Brotherson 1978). These sites have pioneer-type soils, and it is not uncommon to find mountain mahogany plants growing out of cracks in the slickrock.

Methods

Field work was conducted during the summer and fall of 1977. Five plots, dominated by mountain mahogany, and five adjacent plots, dominated by jumiper, were selected for study. The sites chosen exhibited minimum evidence of direct human disturbance or influence of past domestic grazing. Study plots were confined to the same slope, elevation and exposure. Five individuals each of mountain mahogany and juniper were randomly selected from each of the stands for analysis. Twigs from each of the five individuals which were within easy reach (those most likely to be taken by grazing animals) were randomly selected, harvested (October 10, 1977), and bagged for laboratory analysis.

Soil samples were taken from open areas between plants and from underneath the plant canopy of each species. Soils were sampled with a tube type soil probe to a depth of 15 cm. This depth was considered adequate because mean soil depth per plot to bedrock was 13 cm in the mountain mahogany communities (Greenwood and Brotherson 1978). Also Ludwig (1969) in a study of the different foothill communities in Utah showed that the surface decimeter of soil when sampled with reference to mineral concentrations yielded 80% of the information useful in correlations with plant data. Holmgren and Brewster (1972) also showed in a study of desert shrub communities that greater than 50% of the fine roots (those most likely to absorb soil minerals) were found concentrated in the upper 15 cm of the soil profile. Ten samples were taken at each plot (five underneath plants and five between plants) and later lumped by category for laboratory analysis. The five plant samples from each plot were also lumped for analysis.

Zinc, manganese, iron, and copper were extracted from the soils by the use of DTPA-diethylenetriaminepenta-aceticacid, extracting agent (Lindsay and Norvell 1969). Potassium, magnesium, calcium, and sodium ions were extracted with neutral normal ammonium acetate (Jackson 1958; Hesse 1971; Jones 1973). Individual ion concentrations were determined using a Perkin-Elmer Model 403 atomic absorption spectrophotometer (Isaac and Kerber 1971). Soil phosphorus was extracted by sodium bicarbonate (Olsen et al. 1954). Total nitrogen analysis was made using a macro-kjeldahl procedure (Jackson 1958).

Harvested plant samples were air-dried, weighed and ashed at 450° for 24 hours. Analyses of the ash were made with the atomic absorption spectrophotometer.

Data analysis consisted of computing means and standard deviations for each ion (Snedecor and Cocran 1976). Tests of significance were done using a two-way analysis of variance and F-test for soils and a one way analysis of variance and F-test for the plants (Snedecor and Cochran 1976).

Results and Discussion

Ion concentrations in the soil ranged from a low of 0.5 ppm for copper to 8,866 ppm for calcium (Table 1).

Soils from beneath plant canopies had significantly higher ($p < 0.01$) nitrogen concentration than soils from open areas between plants. This result is not unexpected since there is much more organic matter under the canopies than outside them. No other mineral concentrations differed significantly between the canopies and open areas.

Table 1. Chemical concentration of selected ions in soils from underneath and between plants in mountain mahogany and juniper communities. Numbers represent concentration (ppm) means plus or minus one standard deviation. Means are based on five pooled soil samples in each category from each of the five study plots. Analyses are based on soils collected in late August.

Element	Under mt. mahogany (ppm)	Between mt. mahogany (ppm)	Under juniper (ppm)	Between juniper (ppm)
Zn	2.2 ± .2	1.8 ± .3	2.3 ± .3	2.4 ± .3
Cu	0.6 ± .1	0.6 ± .2	0.5 ± .1	0.6 ± .1
Mn	3.7 ± .7	3.5 ± .5	4.2 ± .6	4.5 ± .9
Fe	7.2 ± 1.6	4.5 ± 1.1	5.6 ± 2.5	12.4 ± 15.1
K	110.3 ± 45.7	108.1 ± 79.6	97.5 ± 24.3	72.2 ± 26.5
Ca	7552.0 ± 1726.7	8866.4 ± 846.6	5532.8 ± 1984.8	6575.2 ± 3757.4
Mg	311.2 ± 108.8	380.8 ± 192.8	237.6 ± 98.4	218.4 ± 83.4
Na	36.7 ± 2.8	40.5 ± 9.8	43.4 ± 14.9	31.3 ± 4.6
P	3.8 ± 0.3	5.3 ± 1.2	14.4 ± 7.6	8.6 ± 6.9
N[1]	552.0 ± 86.0	406.0 ± 91.0	491.0 ± 112.0	441.0 ± 104.0

[1]Indicates significant differences in levels of ion concentrations in soils from underneath and between the plants.

The ions zinc, manganese, calcium, magnesium, and phosphorus were significantly different ($p<0.01$) in concentrations in the soils of the two communities (Table 2). Zinc, manganese, and phosphorus were higher in the juniper substratum while calcium and magnesium were in higher concentrations in the mountain mahogany soils. These patterns should be expected since the mountain mahogany soils are shallow and pioneer in character; thus they are much less weathered than the soils of the juniper sites.

Table 3 indicates differences in levels of ion concentrations between mountain mahogany and juniper tissues.

Table 2. Results of significance tests (analysis of variance) on environmental factors with reference to patterns ion concentrtion in the different treatments.

Factors compared in tests of significance	Elements: Zn	Cu	Mn	Fe	K	Ca	Mg	Na	P	N
Juniper soils vs. mt. mahogany soils	.01	NS	.01	NS	NS	.01	.01	NS	.01	NS
Soils between plants vs. soils underneath plants	NS	NS	NS	NS	NS	NS	NS	NS	NS	.01
Plant tissue differences: Juniper vs. mt. mahogany	.01	.01	NS	NS	NS	.01	.01	NS	.01	.01

Table 3. Chemical concentrations (ppm) of selected ions in the tissue of mountain mahogany and juniper. Means plus or minus one standard deviation are shown. Analyses are based on tissue collected in early October.

Element	True mt. mahogany (ppm)	Utah juniper (ppm)
Zn[1]	34.2 ± 9.9	16.1 ± .8
Cu*	28.9 ± 11.4	10.7 ± .9
Mn	12.0 ± 3.5	13.1 ± 1.6
Fe	166.4 ± 134.1	146.2 ± 18.9
K	3086.0 ± 414.1	3526.0 ± 528.3
Ca*	5486.0 ± 3271.8	14474.0 ± 3485.6
Mg*	2632.0 ± 2482.6	1538.0 ± 430.3
Na	386.6 ± 143.3	329.8 ± 57.2
P*	731.8 ± 160.7	484.4 ± 48.6
N*	9048.0 ± 987.0	7676.0 ± 614.0

[1]Indicates significant differences ($p > 0.01$) in levels of ion concentration in plant tissue. Means and standard deviations are based on pooled samples of five individual plants from each of the five study plots.

Zinc, copper, magnesium, phosphorus, and nitrogen concentrations were significantly higher (< 0.01) in mountain mahogany than in juniper, while calcium concentrations were greater ($p<0.01$) in juniper than in mountain mahogany. Other ions: sodium, potassium, iron, and manganese, showed no significant differences in concentrations between the two species.

Observed differences of ion concentrations in the two plant species can probably be attributed to two factors: (1) differential capacities for mineral absorption (2) inherent differences in the mineral supply of the soil in which the plants grow (Russell 1973). It has previously been reported that available minerals in soils are correlated with mineral concentrations in plants that grow in those soils (i.e. when there is scarcity of minerals in the soil, this scarcity will also be reflected in plant tissue mineral concentrations) (Beeson 1941; Russell 1973). However, such correlation was not always found in this study.

Table 4 compares plant-soil mineral relationships expressed as ratios of mineral concentration in plant tissues to the concentration in the soil. Ratios varied from 0.7 for calcium to 161.6 for phosphorus in true mountain mahogany. Zinc, copper, manganese, iron, magnesium, sodium, phosphorus, and nitrogen showed higher plant to soil concentrations for mountain mahogany than for juniper. Utah juniper showed higher relative potassium and calcium concentrations. In all cases except calcium in true mountain mahogany, the ions were shown to be concentrated from the soil to the plants. In most cases where mineral concentrations were lowest in the soil, the concentration ratios beneath a plant species were greatest in the plants tissue. True mountain mahogany showed these patterns in five of the seven cases where such relationships were apparent. This may indicate the ability of the species to do well under pioneer conditions.

Table 5 compares the mineral compositions in the species of juniper and mountain mahogany with other shrubs and life forms. The two species studied here are low in concentration of manganese, iron, potassium, and phosphorus when compared to the other life forms but have similar concentrations of all other ions except for copper in mountain mahogany (Table 5).

Because of the high concentration of copper ($x = 28.9$ ppm, range 17 to 44 ppm) in mountain mahogany tissue, copper toxicity is a distinct possibility in ruminants which forage on it. Baker (1974) observed that copper concentrations this high in forages could be toxic to some ruminant

Table 4. Ratios of plant/soil concentrations of selected ions. Asterisk indicates those areas where mineral concentrations in the soils were lowest and yet plants concentrated the ions to levels higher than in the corresponding species (Utah juniper or true mountain mahogany).

Plant species	Elements									
	Zn	Cu	Mn	Fe	K	Ca	Mg	Na	P	N
Utah juniper	7	19.5	3.0	16.3	41.5*	2.4*	6.8	8.8	42.2	16.5
True Mt mahogany	16.8*	46.6	3.4*	28.3	28.3	0.7	7.6	10.0	161.*	18.9

Table 5. Mineral composition of tissue of mountain mahogany and juniper from the Uintah Basin, Utah, in relation to published data on other plant lifeforms. Analyses based on tissue collected in early October (means in ppm).

Species	Element Concentrations (ppm)									
	Zn	Cu	Mn	Fe	K	Ca	Mg	Na	P	N
Juniper	16.1	10.1	13.1	146.2	3526.0	14474.0	1538.0	329.8	484.4	7676.0
Mt. mahogany	34.2	28.9	12.0	166.4	3086.0	5486.0	2632.0	386.6	731.8	9048.0
Grasses	27.1[4]	8.9[4]	162.0[4]	398.0[4]	18180.0[1]	5280.0[1]	1280.0[2]	300.0[1]	1920.0[1]	10710.0[1]
Forbs	40.6[4]	6.9[4]	250.0[4]	300.0[3]	3922.0[1]	18420.0[1]	2100.0[3]	190.0[1]	2970.0[1]	13800.0[1]
Trees	18.2[5]	10.8[5]	14.0[5]	138.1[5]	3505.0[5]	1246.8[5]	1408.0[5]	308.5[5]	394.8[5]	6949.0[5]
Other shrubs	43.9[4]	4.9[4]	89.3[4]	452.8[4]	17680.0[1]	12400.0[1]	6355.0[2]	800.0[1]	2050.0[1]	9020.0[1]

Adapted from Harner and Harper (1973).
[2]Adapted from Charley (1977).
[3]Adapted from Spedding (1971).
[4]Adapted from Wallace and Romney (1972).
[5]Adapted from Rodin and Basilerich (1965).

animals. However, under winter range conditions, animals would probably be poisoned only if mountain mahogany were their sole diet.

Since mineral levels in both juniper and mountain mahogany compare favorably with other forage species (Table 5), they may be considered as valuable sources of them for ruminant animals. However, since juniper is less palatable than mountain mahogany and also since in the study area it showed a calcium/phosphorus ratio of 28 to 1, it appears highly unlikely that animals could do well on it. Mountain mahogany on the other hand is highly palatable and since it has more desirable calcium/phosphorus ratio (7.5 to 1) it could be a valuable source of winter forage. Its high mineral content could be especially important to deer in late winter after they have shed their antlers or are heavy with fawn, since at such times their nutritional requirements for minerals would be unusually high (Harrison Matthews 1952; Spedding 1971).

Literature Cited

Baker, D.E. 1974. Copper: soil, water, plant relationships. Federation Proc. 33: 1188-1193.

Beeson, K.C. 1941. The mineral composition of crops with particular reference to the soil in which they were grown. U.S. Dep. Agr. Misc. Pub. 369.

Charley, J.L. 1977. Mineral cycling in rangeland ecosystems, in Range Plant Physiology ed. by Sosebee, R.E. Range Science Series No. 4.

Grahame, E, H.E. Albiston, and L.B. Bull. 1949. Investigations into the etiology and control of enzootic (Toxaemic) Jaundice of Sheep. Austral. Vet. J., 25: 202.

Greenwood, L.R., and J.D. Brotherson. 1978. Ecological relationships between pinyon-juniper and true mountain mahogany stands in the Uintah Basin, Utah. J. Range Manage. 31: 164-167.

Hall, A.D. 1905. The analysis of the soil by means of the plant. J. Agr. Sci., 1:65-68.

Harner, R.F., and K.T. Harper. 1973. Mineral compositon of grassland species of the Eastern Great Basin in relation to stand productivity. Can. J. Bot., 51: 2037-2046.

Harrison Matthews, L. 1952. British mammals. Collins, London. 423 p.

Hesse, P.R. 1971. Textbook of Soil Chemical analysis. William Clowes and Sons, Ltd., London. 520 p.

Hill, H.E. 1951. Fluorine poisoning. Auburn Vet., 7: 127.

Holmgren, R.C., and S.F. Brewster. 1972. Distribution of organic matter reserve in a desert shrub community. U.S. Dep. Agr.Forest Serv. Res. Pap. INT-130. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Isaac, R.A., and J.D. Kerber. 1971. Atomic absorption and flame photometry: techniques and uses in soil, plant and water analysis. In L.M. Walsh (ed). Instrumental Methods for Analysis of Soils and Plant Tissue. Soil Sci. Soc. Amer. Wis., p. 17-38.

Jackson, M.L. 1958. Soil Chemical Analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J. 498 p.

Jones, J.B. 1973. Soil testing in the United States, Comm. Soil Sci. Plant Anal. 4: 307-322.

Kingsbury, J.M. 1964. Poisonous Plants of the United States and Canada. Prentice-Hall, Inc. Englewood Cliffs, New Jersey. 626 p.

Lindsay, W.L., and W.A. Norvell. 1969. Development of a DTPA micronutrient soil, test, Agron. Abstracts. p. 84. Equilibrium relationships of Zn^{2+}, Fe^{3+}, Ca^{2+}, and H^{+} with EDTA and DTPA in soil, Soil Sci. Soc. Amer. Proc. 33: 62-68.

Ludwig, J.A. 1969. Environmental interpretation of foothill grassland communities of northern Utah. Unpublished Ph.D. Diss. Univ. of Utah. Salt Lake City, Utah. 100 p.

Midgley, A.R., and V.L. Weiser. 1936. Need and use of potash on Vermont pastures. Vt. Agr. Exp. Sta. Bull. 403.

Olsen, S.R., C.V. Cole, F.S. Watanabe, and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dep. Agr. Cir. No. 939.

Plummer, A.P. 1969. Restoring big-game range in Utah. Pub. No. 683. Utah Division of Wildl. Resources. 183 p.

Rodin, L.E., and N.I. Basilevich. 1965. Production and Mineral Cycling in Terrestrial Vegetation. (English translation by G.E. Fogg. 1967). Oliver Boyd. Edinburgh. 288 p.

Russell, E.W. 1973. Soil Conditions and Plant Growth. 10th ed. Jarrold and Sons Ltd., Norwich, Great Britain. 849 p.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical Methods. 6th Ed. Iowa State Univ. Press, Ames, Iowa. 593 p.

Spedding, C.R.W. 1971. Grassland Ecology. Oxford University Press, Ely House, London. 221 p.

Underwood, E.J. 1971. Trace elements in human and animal nutrition. 3rd ed. Academic Press, New York. 543 p.

Wallace, A., and E.M. Romney. 1972. Radioecology and ecophysiology of desert plants at Nevada test site. Environmental Radiation Division, Laboratory of Nuclear Medicine and Radiation Biology and Agricultural Sciences, Los Angeles Soil Science and Agricultural Engineering, Univ. of California, Riverside. 439 p.